

## A gradual shift in initial foot-to-ground contact patterns depending upon acceleration

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### Introduction

Running involving sub-maximal accelerations occurs very frequently during sports. Insight into the biomechanics of this type of unsteady locomotion therefore is of interest for *e.g.* footwear design and sports training.

A net acceleration of the body centre of mass (BCOM) is realized by increasing the net horizontal impulse by proportionally less braking and more propulsion (Van Caekenberghe et al., in press), while controlling total body angular momentum. The increase in net impulse is related to a more anterior ground reaction force (GRF) vector and is accompanied in kinematics by an equally more forward body lean (Kugler and Janshen, 2010). Body lean is quantified as the angle relative to the vertical of a line between the BCOM and the centre of pressure (COP) which can be regarded as a moving pivot-point mechanism, among others determined by its initial contact location on the foot.

Maximal accelerations during sprinting are characterized by an active (clawing) touchdown on the forefoot (Johnson and Buckley, 2001). Given the gradual change in force characteristics and body orientation, a gradual change in foot fall patterns towards the touchdown observed during maximal accelerations is expected during sub-maximal accelerations. The **location of initial foot to ground contact** is hypothesized to shift anteriorly on the foot (change towards forefoot strike (FFS)) with larger accelerations. However, at steady state, interindividual

differences in the location of initial foot contact (already) exist. Rearfoot strikers (RFS) have a larger margin of progression to the FFS pattern than midfootstrikers (MFS), as such a larger acceleration effect is expected in the RFS population. Another means of quantifying initial foot contact consists in the **foot-to-ground angle at initial contact**, which is hypothesized to enlarge (i.e. toes gradually lower than the heel) as acceleration enlarges.

### Purpose of the study

The aim is to discuss the acceleration effect on the location of initial contact on the foot and on the foot segment angle during sub-maximal running accelerations overground.

### Methods

9 subjects ran on a 30m long runway with 4 force platforms (1000 Hz) and a 2m Footscan (RSscan®, 500 Hz). 3D kinematics were recorded (Qualisys®) and analyzed (Visual 3D, C-Motion®). Per subject  $72 \pm 29$  stances were analyzed. Subjects ran at different constant speeds (2-7 m/s) and accelerated at sub-maximal accelerations (0-4 m/s<sup>2</sup>).

A multiple linear regression analysis (independent variables: acceleration and speed (covariate)) was used to determine the acceleration effect on the dependent variables. Acceleration was calculated by means of the GRF. Speed was calculated as the mean speed of the BCOM. Initial foot contact location was determined as the percentage of total foot length at which the COP is starting from the

heel when the vertical GRF reaches 10% of the maximal vertical force (i.e., strike index [SI], Williams and Cavanagh, 1987). Foot abduction is taken into account in the calculations. Foot-ground segment angle is the foot angle in the sagittal plane normalized to neutral standing position with a positive angle indicating toes lower than the heel.

## Results

At speeds in between 3 and 4 m/s the mean SI of the subjects is  $0.29 \pm 0.18$ . Based upon this variable, the subjects were divided in a RFS group (5 subjects, SI:  $0.15 \pm 0.02$ ) and a MFS group (3 subjects, SI:  $0.48 \pm 0.05$ ). In one other subject, RFS and FFS were observed. The acceleration coefficient in the regression indicates the change in SI and foot-ground angle per  $1 \text{ m/s}^2$  acceleration rise over the whole speed (2-7 m/s) range. Results are given in Table 1.

The foot angle changes from a negative (toes up) towards a positive angle (heel up) when acceleration enlarges.

## Discussion and conclusion

Per  $\text{m/s}^2$  rise in sub-maximal acceleration, the footstrike occurs on average 16% more towards the toes, and the foot segment angle at initial contact enlarges by  $\sim 7^\circ$ . This applies for habitual RFS as well as MFS as acceleration effects do no statistically differ (Mann Whitney U-test,  $p > 0.1$ ).

Through their correlations with acceleration, foot fall patterns are also related to a gradual decrease in braking impulse in favor of the propulsive impulse (Van Caekenberghe et al., in press). This however necessitates a more backward rotation of the leg (from hip to ankle) upon contact to align the BCOM to the GRF vector and thus control the total body angular momentum. This backward leg rotation was demonstrated to be related to the active touchdown in maximal sprint accelerations (Hunter et al., 2005). Altogether these changed foot fall patterns probably create a neuromechanical advantage in decreasing braking and enlarging propulsion. Additionally, the gradually shorter COP-path due to the gradually higher SI also relates to a shorter contact time (Van Caekenberghe et al., in press), which has been considered beneficial for sprinting (Wood, 1987).

## References

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Table 1. Acceleration effects on initial foot –to-ground contact patterns

	acceleration effect on							
	strike index				initial foot-ground angle			
	$(\Delta \text{SI}/(\text{m s}^{-2}))$		$R^2$		$(\Delta^\circ/(\text{m s}^{-2}))$		$R^2$	
	M	sd	M	sd	M	sd	M	sd
ALL (n=9)	0.16	$\pm 0.08$	0.47	$\pm 0.21$	6.96	$\pm 3.75$	0.34	$\pm 0.30$
RFS (n=5)	0.18	$\pm 0.09$	0.52	$\pm 0.26$	8.32	$\pm 3.06$	0.46	$\pm 0.30$
MFS (n=3)	0.15	$\pm 0.06$	0.43	$\pm 0.17$	4.69	$\pm 4.28$	0.14	$\pm 0.21$